Research Article:

FISH DIVERSITY WITH SEASONAL VARIATION OF WATER QUALITY IN FISHERIES RESERVOIR, CHITWAN

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ABSTRACT

A study was conducted to compare the seasonal variation of fish diversity, water quality and catch per unit effort (CPUE) of Fisheries Reservoir in four seasons *viz.*, spring, summer, autumn and winter from October, 2016 to September, 2017. Water and fish sampling were done monthly from 3 different sites (water inlet, mid part and near water outlet) of reservoir and grouped into four seasons and compared. A total of 17 fish species representing 7 orders and 11 families with 15 genera were found in reservoir. Cypriniformes was the dominating fish order representing a total of 7 species. A total of 14 species were recorded in the autumn season, 13 species in both the spring and summer seasons, and 10 species in winter season. The abundance and CPUE of fishes were significantly higher in spring season (184±57.2 no. of fishes and 7360±2288.7 fishes/day, respectively) as compared to other seasons. The water quality parameters, depth, water temperature, total ammonium nitrogen, and soluble reactive phosphorus were higher in summer season (150.0±2.9 cm, 29.2±0.8°C, 0.78±0.17 mg/L and 0.035±0.004 mg/L, respectively) whereas dissolved oxygen, total dissolved solids and electrical conductivity in winter season (4.4±0.2 mg/L, 135.7±0.3 mg/L and 272.6±0.5 µS/cm, respectively). The value of total nitrogen was higher in spring season (1.96±0.26 mg/L). The parameters secchi disk visibility, pH, Total alkalinity, total phosphorus, nitrite nitrogen and chlorophyll-a were statistically similar in all four seasons. A high density of phytoplankton were observed in the summer season (373.3±17.6 no./L) while the density of zooplankton in the autumn season (160.0±19.3 no./L). Fish abundance declined with decreasing dissolved oxygen, total nitrogen, chlorophyll-a and zooplankton density while it rises with decreasing water depth, secchi disk visibility, total ammonium nitrogen and nitrite nitrogen. Most of the measured water quality parameters were in the desirable range for fish while the number of fish species decreased as compared to the previous studies. To restore fish diversity in the reservoir, habitat improvement through the management of water quality parameters, the stocking of native species, and the avoidance of fishing may be helpful.

Key words: Abundance, catch per unit effort, cypriniformes, four seasons

INTRODUCTION

Fisheries Reservoir lies in Rampur ward no. 15 of Bharatpur Metropolitian City, Chitwan district, Central Nepal at a latitude of 27^0 39' 24.52"N, longitude 84^0 20' 58.77" E and an altitude of 167 m above mean sea level. The reservoir was built by making weir over Rampur ghol in 2016 near to the Fisheries Program, Agriculture and Forestry University (AFU). The ghol covers an area of 23 ha and it is about 9 km south west from the Narayangarh Bazar (Jha & Shrestha, 2000). Out of total area of ghol, Fisheries Reservoir covers about 0.33 ha. It is a freshwater marshy land (wetland) surrounded by agricultural lands on the northern edge of AFU. Wetland refers to swampy places with flowing or still water, which may also include reservoirs, marshy rice fields, and land that is flooded with water inside or close to a human settlement (National Wetland Policy, 2003). Wetlands are crucial for maintaining plant and animal diversity since they are home to many different species of flora and wildlife. They are crucial habitats for endemic, uncommon, and threatened plant and animal species. (Majupuria & Majupuria, 2006). There are more than 27,800 species of fish in the world of which about 10,000 are freshwater fish (Shrestha, 2008). Previous study on the Rampur swamp by Jha and Shrestha (2004) reported 40 fish species belonging to 6 orders, 15 families and 28 genera. Another study by Oli et al. (2013) reported a decline in species as compared to the previous study because they only recorded 22 species of fish belonging to 13 families and 5 orders. The water quality is the most important component that influence on the distribution of aquatic biota (De, 2000) as well as in the health of aquatic habitats, including habitats for fish, plankton, and other species (Bratram & Ballence, 1996). It has been noted that seasonal variations in temperature and precipitation are accompanied by variations in reservoir water quality (Zhang et al., 2015). The water quality of the reservoir is likely changing as it receives the loads of pollutants from the adjacent anthropogenic activities (Nyanti et al., 2015). To delineate the pollution in the reservoir the monitoring of water quality parameters is important. There was a gap in study since the reservoir was constructed. This study aims to close this knowledge gap by determining the current state of fish species, water quality indices, and seasonal fluctuations.

MATERIALS AND METHODS

Study site

The study was carried out in Fisheries Reservoir, Rampur, Chitwan located at latitude 27^{0} 39' 25" N, longitude 84^{0} 20' 59" E and altitude of 177 m above sea level near to Fisheries hatchery complex of Fisheries Program, AFU from October, 2016 to September, 2017. The Fisheries Reservoir covers about 0.33 ha of area. Three sites were selected including the water inlet, near the water outlet and the middle part of the reservoir for representative samples. Three sampling points were marked around one meter of the selected sites.

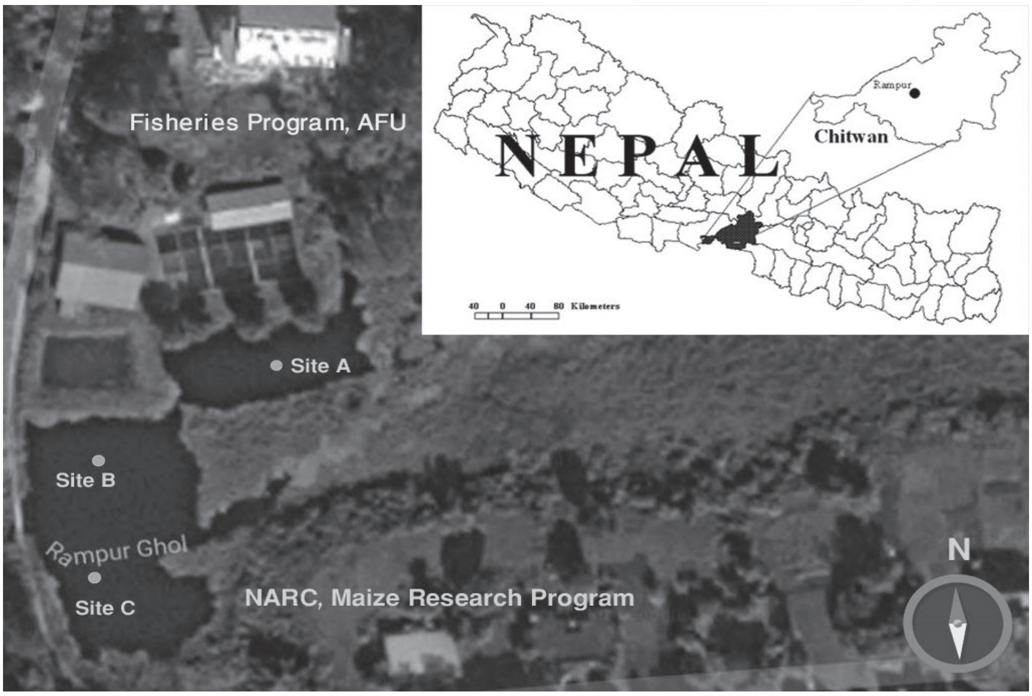

Fig. 1. Selected three sites in Fisheries Reservoir, Rampur, Chitwan (Site A, Site B and Site C)

Fish diversity

Monthly fish sampling was done in day time from 10 am to 4 pm from the selected sites with the help of cast net having mesh size of 6 mm x 6 mm. The circumference and diameter of the net were 7.3 m and 2.32 m, respectively. A local fisherman was hired for this purpose. The fish species were identified according to a key developed by Shrestha (2019) and preserved in 10% formalin solution.

Total fish catch during each season was calculated by mean fish caught in three months. Shannon-Wiener diversity indexes (H), species richness (S) and evenness index (E) were calculated to measure the fish diversity in four seasons during the study period.

Shannon wiener diversity index

$H = \sum_{i=1}^{s}$ pi ln pi

Species richness

S = total number of observed species per area of defined ecosystem

Evenness index

E = H / ln S

Where, H = diversity index, s = number of species, Pi = (n/N) = relative abundance, n = number of individual for each species, N = the total number of individuals, E = the similarity or evenness index and ln = natural logarithm

Catch per unit effort

Season wise catch per unit effort (CPUE) were calculated and compared. A fisherman used cast net for fishing and time took per fishing was noted. A total number of fishes collected were counted. During calculation, it was assumed 12 hours' equal to a day. Fishing effort was calculated in terms of time (hours) spent on fishing. CPUE was calculated using the following formulae:

$$\text{CPUE} = \frac{\text{Total number of fishes catch}}{\text{Fishing efforts}}$$

Water quality analysis

Water sampling was done early in the morning between 6 and 7 am monthly with column water sampler from the selected sites in the Fisheries Reservoir. The water quality parameters water temperature, Secchi disk visibility, DO, pH, total dissolved solids and electrical conductivity were measured *in situ* by digital multi-meter (Hanna, Model-HI 98194). The secchi disk visibility was measured between 8 and 11 am. The depth of the reservoir was measured using a marked pole. A liter of water sample was collected in plastic bottle for the laboratory analysis of other water quality parameter as total alkalinity, total nitrogen, total phosphorus, total ammonium nitrogen, nitrite nitrogen, soluble reactive phosphorus and chlorophyll-*a* by standard methods (APHA, 2012). For the quantitative determination of plankton, five liters of surface water (up to 50 cm) was sampled between 8 and 10 am and filtered through plankton net (mesh size 5 µm) and collected in a plankton tube. The samples were then preserved in formalin solution (4%) and density estimations (numbers/volume of water samples) was done with the help of Sedge wick-Rafter cell under microscope (Welch, 1984). Zooplankton is differentiated from phytoplankton based on large size and animal-like body shape having appendages.

Statistical analysis

The collected data were analyzed by using SPSS (Version 21) software package. Shannon diversity index was used to compare fish diversity in four seasons. Water quality parameters, fish abundance and CPUE were analyzed statistically by using one-way ANOVA followed by Duncan's multiple range test at 5% level of significance. Karl Pearson's correlation coefficient of fish abundance with water quality parameters is calculated for four seasons to know the relation according to Gupta (1988). Microsoft Excel 2010 was used to prepare diagrams, charts and graphs. All average values were given with ± S.E.

RESULTS

Fish diversity

A total of 17 fish species belonging to 15 genera, 11 families and 7 orders were caught in the reservoir. Among these species 7 were common, 3 were uncommon and 7 were rare (Table 1). Based on total catch, the top five species were *Puntius sophore* (33.7%), *Trichogaster fasciatus* (16.3%), *Puntius ticto* (16.1%), *Esomus danrica* (10.2%) and *Mystus bleekeri* (6.1%).

Cypriniformes was the most dominating order having 7 species with 67.9% total catch, followed by Anabantiformes having 3 species with 19.8% total catch and Siluriformes having 3 species with 7.2% total catch. The orders Beloniformes, Cichliformes, Synbranchiformes and Gobiiformes have 1 species with 3.5, 0.9, 0.5 and 0.2 percent total catch respectively.

The total species recorded is more in autumn season (14 species), 13 species in summer and spring seasons. Less number of species recorded is 10 in winter season.

Based on the total catch, the highest numbers of individual fishes were recorded in spring season (185), followed by winter season (95), summer season (84) and lowest in autumn season (66).

Table 1. Fish diversity in Fisheries Reservoir during the study period

S.N.	Fish species	Family	Order	Spring	Summer	Autumn	Winter	Total catch (number)	Total catch (%)	Status
1	*Cirrhinus mrigala mrigala*	Cyprinidae		0	0	1	0	1	0.2	R
2	*Danio devario*	Cyprinidae		8	4	5	9	26	6.1	R
3	*Esomus danrica*	Cyprinidae		13	9	8	14	44	10.2	C
4	*Paracanthocobitis botia*	Nemacheilidae	Cypriniformes	0	0	1	0	1	0.2	C
5	*Pethia conchonius*	Cyprinidae		3	1	1	1	6	1.4	UC
6	*Puntius sophore*	Cyprinidae		70	34	17	24	145	33.7	C
7	*Puntius ticto*	Cyprinidae		27	14	15	13	69	16.1	C
8	*Channa orientalis*	Channidae		1	1	0	0	2	0.5	R
9	*Channa striata*	Channidae	Anabantiformes	7	2	1	3	13	3	UC
10	*Trichogaster fasciatus*	Osphronemidae		39	8	8	15	70	16.3	C
11	*Heteropneustes fossilis*	Heteropneustidae		0	1	1	0	2	0.5	R
12	*Mystus bleekeri*	Bagridae	Siluriformes	6	6	5	10	27	6.2	C
12	*Ompok bimaculatus*	Siluridae		1	1	0	0	2	0.5	R
14	*Glossogobius giuris*	Gobiidae	Gobiiformes	0	0	1	0	1	0.2	R
15	*Macrognathus pancalus*	Mastacembelidae	Synbranchiformes	1	0	0	1	2	0.5	R
16	*Oreochromis niloticus*	Cichlidae	Cichliformes	2	1	1	0	4	0.9	UC
17	*Xenentodon cancila*	Belonidae	Beloniformes	6	2	2	5	15	3.5	C
	Total	**11**	**7**	**185**	**84**	**66**	**95**	**430**	**100**	

C= common, UC= Uncommon, R= Rare

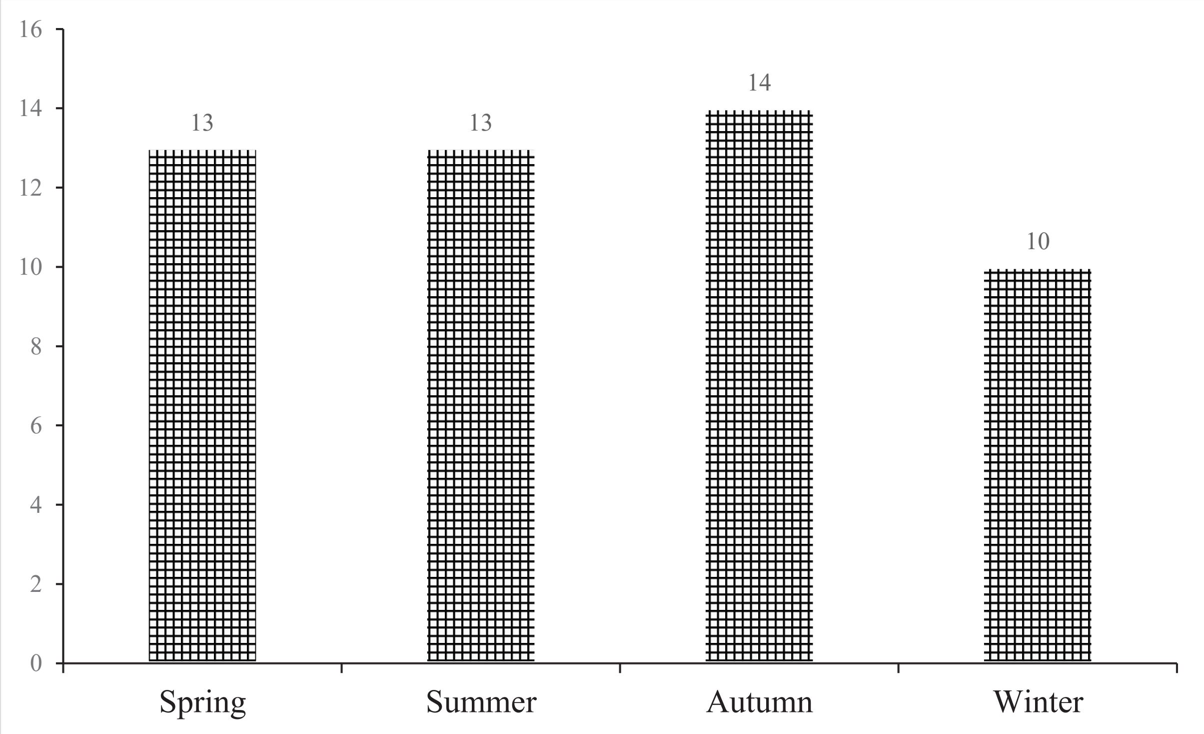

Fig. 2. Number of fish species recorded in different seasons in Fisheries Reservoir during the study period

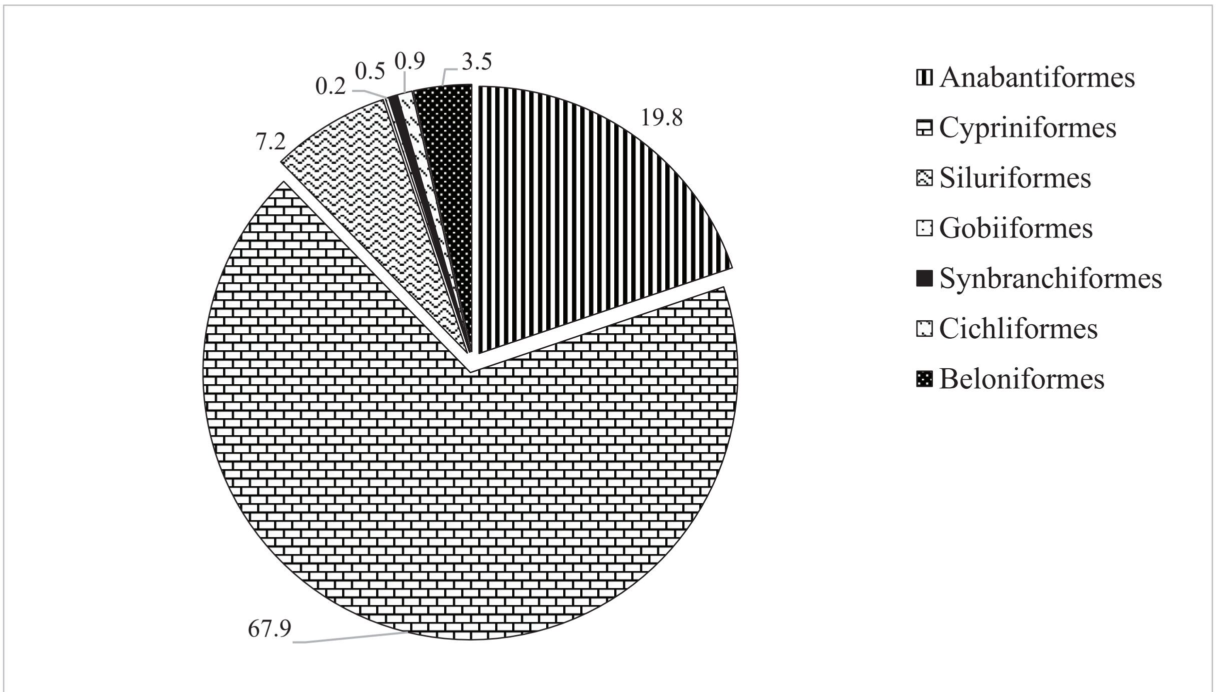

Fig. 3. Total catch percentage of fish species of different orders recorded in Fisheries Reservoir during the study period

Abundance and CPUE

The abundance and CPUE were significantly higher in the spring season (184 ± 57 and 7360 ± 22 fishes/day, respectively) as compared to other seasons. Statistically, the abundance and CPUE was similar in summer, autumn and winter seasons. The lower number of fishes caught was 66 and fishes/day was 2640 in autumn (Table 2).

Table 2. Abundance and CPUE of fishes of Fisheries Reservoir in four seasons during study period

Parameters	Seasons			
	Spring	Summer	Autumn	Winter
Abundance (no. of fishes)	184 ± 57.2[a] (118 – 218)	83 ± 46.9[b] (53 - 137)	66 ± 3.0[b] (63 – 69)	93 ± 30.5[b] (63 - 124)
CPUE (fishes/day)	7360 ± 2286.7[a] (4720 – 8720)	3320 ± 1874.5[b] (2120 - 5480)	2640 ± 120.0[b] (2520 – 2760)	3707 ± 1221.4[b] (2520 - 4960)

Diversity index

Shannon diversity index, species richness and evenness index are given in Table 3. All the calculated indexes were statistically similar as compared to seasons. Shannon diversity index (H) ranges from 0 to 5 with value of 1.99 and below indicates very low according to Fernando (1998). In this study, Shannon diversity index is less than 1.99 throughout the seasons representing less diverse fish species in the reservoir.

The species richness value represents the total number of fish species in a specific area of water body and it may vary from 9 to 13 species in different seasons.

Evenness index may vary from 0 to 1, the value 1 represents all species are equally abundant and 0 represents one species dominant. According to this study, fish species are moderately to highly equally abundant throughout the seasons, with an average evenness index score of 0.74 to 0.85.

Table 3. Shannon diversity index (H), Species richness (S) and evenness index (E) of Fisheries Reservoir in four seasons

Parameters	Seasons			
	Spring	Summer	Autumn	Winter
Shannon diversity index (H)	1.78±0.07[a] (1.69-1.91)	1.79±0.10[a] (1.66-1.98)	1.95±0.08[a] (1.81-2.09)	1.88±0.05[a] (1.81-1.96)
Species richness (S)	11[a] (10-12)	10[a] (9-11)	10[a] (7-13)	9[a] (9-9)
Evenness index (E)	0.74±0.05[a] (0.68-0.83)	0.77±0.03[a] (0.73-0.83)	0.84±0.05[a] (0.76-0.93)	0.85±0.02[a] (0.82-0.89)

Water quality parameters

Mean value of water quality parameters of Fisheries Reservoir in four seasons are presented in Table 4**.** The parameters except secchi disk visibility, pH, total alkalinity, total phosphorus, nitrite nitrogen and chlorophyll-a were statistically significant within four seasons.

In physical water quality parameters, the mean depth of the reservoir was significantly highest in summer season (150±2.9 cm) and autumn season (143±9.0 cm) and lowest in spring season (71±8.4 cm). The water temperature was significantly lowest in the winter season (17.0±0.6°C) as compared to summer (29.2±0.8°C), autumn (25.2±2.7°C) and spring seasons (23.7±1.7°C). The water was more transparent in autumn (59±20.3 cm) and summer season (55±22.7 cm) as compared to winter (32±2.1 cm) and spring season (25±1.3 cm).

In chemical parameters, the dissolved oxygen (DO) is significantly higher in winter (4.4±0.2 mg/L) and spring season (4.3±0.4 mg/L) than in autumn season (1.9±0.6 mg/L). The overall mean value of pH was neutral and it ranged from 6.9 to 7.9. The total dissolved solids (TDS) and electricity conductivity (EC) values were highest in winter season (135.7±0.3 mg/L and 272.6±0.5µS/cm) and lowest in summer season (111.3±9.3 mg/L and 223.5±18.4 µS/cm), respectively. The mean total alkalinity was statistically similar in all seasons and grand mean value was 132.4 mg/L as $CaCO_3$. The total nitrogen (TN) was significantly higher in the spring season (1.9±0.3 mg/L) whereas TN values were statistically similar in autumn, winter and summer seasons. The mean of total ammonia nitrogen (TAN) was significantly higher in the summer season (0.78±0.17 mg/L) as compared to winter (0.1±0.05 mg/L) and summer season (0.11±0.04 mg/L). The nitrite nitrogen value appropriate throughout the study period and statistically similar in all seasons with mean value of 0.036 mg/L.

The total phosphorus was statistically similar in all seasons with 0.08 mg/L of mean value whereas the soluble reactive phosphorus (SRP) was significantly higher in summer season (0.035±0.004 mg/L) as compared to winter season (0.005±0.003 mg/L).

The chlorophyll-a concentration was similar in all seasons with a grand mean value of 7.5 mg/m^3. The density of phytoplankton was significantly higher in the summer season (373.3±17.6/L) whereas the zooplankton was significantly higher in the autumn season (160.0±19.2/L). Both phytoplankton and zooplankton were lower in the winter season (215.6±8.9/L and 97.8±5.8/L), respectively.

Table 4. Water quality parameters of Fisheries Reservoir in four seasons during the study period

Parameters	Seasons				Average
	Spring	Summer	Autumn	Winter	
Depth (cm)	71±8.4^c (45-95)	150±2.9^a (135-170)	143±9.0^a (125-180)	109±15.7^b (80-155)	118.2
Water temperature (ºC)	23.7±1.7^a (20.4-26.9)	29.2±0.8^a (28.3-31.9)	25.2±2.7^a (19.8-29.4)	17.0±0.6^b (14.8-19.1)	23.8
Secchi disk visibility (cm)	25±1.3^a (23-33)	55±22.7^a (25-100)	59±20.3^a (36-100)	32±2.1^a (25-38)	42.7
TDS (mg/L)	127.0±5.5^{ab} (109.2-140.5)	111.3±9.3^b (99.2-133.0)	125.3±4.0^{ab} (112.4-132.8)	135.7±0.3^a (135.0-138.8)	124.8
pH	7.4 (7.1-7.6)	7.5 (7.2-7.9)	7.4 (7.2-7.9)	7.2 (6.9-7.5)	7.4
DO (mg/L)	4.3±0.4^a (2.9-4.9)	3.1±0.9^{ab} (1.4-4.4)	1.9±0.6^b (0.8-3.8)	4.4±0.2^a (3.7-5.2)	3.4
EC (µS/cm)	255.2±11.1^{ab} (218.3-281.0)	223.5±18.4^b (198.3-266.0)	251.2±8.1^{ab} (224.8-265.7)	272.6±0.5^a (270.0-277.7)	250.6
Total alkalinity (mg/L as $CaCO_3$)	122.4±5.8^a (102.9-138.4)	130.6±17.9^a (101.9-165.9)	136.8±10.7^a (118.5-162.8)	139.7±3.0^a (129.8-146.0)	132.4
Total nitrogen (mg/L)	1.9±0.26^a (1.3-2.8)	0.8±0.1^b (0.5-1.1)	0.9±0.5^b (0.1-2.2)	0.8±0.1^b (0.5-1.1)	1.1
Total phosphorus (mg/L)	0.11±0.03^a (0.05-0.18)	0.13±0.06^a (0.04-0.30)	0.05±0.01^a (0.04-0.12)	0.03±0.01^a (0.02-0.06)	0.08
TAN (mg/L)	0.11±0.04^b (0.00-0.21)	0.78±0.17^a (0.34-1.05)	0.60±0.27^{ab} (0.10-1.22)	0.15±0.05^b (0.00-0.52)	0.41
Nitrite nitrogen (mg/L)	0.024±0.004^a (0.014-0.035)	0.027±0.003^a (0.016-0.054)	0.046±0.020^a (0.014-0.135)	0.039±0.010^a (0.011-0.101)	0.034

SRP (mg/L)	0.0084±0.004[ab] (0.002-0.022)	0.035±0.004[a] (0.017-0.088)	0.022±0.016[ab] (0.000-0.058)	0.005±0.003[b] (0.000-0.018)	0.018
Chlorophyll-*a* (mg/m^3)	10.4±1.1[a] (4.5-23.2)	10.7±4.5[a] (2.7-23.2)	5.0±0.9[a] (2.7-9.8)	4.0±1.4[a] (0.0-9.8)	7.5
Phytoplankton density (no./L)	280.0±06.7[b] (180-320)	373.3±17.6[a] (260-520)	253.3±10.2[bc] (180-420)	215.6±08.9[c] (140-280)	280.6
Zooplankton density (no./L)	104.4±05.8[b] (80-160)	113.3±16.8[b] (80-160)	160.0±19.2[a] (100-200)	97.8±05.8[b] (60-140)	118.9

Mean values with the same superscript in the same row are not significantly different at 5% level of significance. Figures in the parenthesis are range value

Correlation of Fish abundance with water quality parameters

The correlation analysis between fish abundance and various water quality parameters revealed distinct relationships (Table 5). Depth exhibited a strong negative correlation with fish abundance (r = -0.92), suggesting that fish tend to be more abundant in shallower waters. Similarly, Secchi Disk Visibility (SDV) and Total Alkalinity (TA) showed strong negative correlations (r = -0.82 and r = -0.83, respectively), indicating clearer and more alkaline waters were associated with lower fish abundance.

Total Ammonia Nitrogen (TAN) and Nitrite Nitrogen displayed strong negative correlations (r = -0.70 and r = -0.71), suggesting toxic effects at higher concentrations that negatively impact fish abundance. Soluble Reactive Phosphorus (SRP) and the number of zooplankton also showed moderate negative correlations (r = -0.52 and r = -0.54, respectively), which may indicate limited food availability or unfavourable water conditions.

In contrast, Total Nitrogen (TN) exhibited a strong positive correlation with fish abundance (r = 0.95), suggesting nutrient enrichment may support greater primary productivity, thereby enhancing fish populations. Chlorophyll-a and Total Phosphorus (TP) showed moderate positive correlations (r = 0.53 and r = 0.40, respectively), further supporting the link between nutrient availability and fish abundance. Dissolved Oxygen (DO) also had a moderate positive correlation (r = 0.68), indicating that higher oxygen levels support aquatic life.

Other parameters, such as water temperature (r = -0.13), Total Dissolved Solids (TDS) (r = 0.20), Electrical Conductivity (EC) (r = 0.21), and pH (r = 0.00), showed weak or negligible correlations with fish abundance. Additionally, the number of phytoplankton displayed a very weak negative correlation (r = -0.02), suggesting limited influence on fish abundance.

Table 5. Correlation coefficient of fish abundance and water quality parameters during the study period

Water quality parameters	Correlation coefficient of Fish abundance
Depth (cm)	-0.92
Water temperature (°C)	-0.13
Secchi disk visibility (cm)	-0.82
Total alkalinity (mg/L as $CaCO_3$)	-0.83
Total ammonium nitrogen (mg/L)	-0.70
Nitrite nitrogen (mg/L)	-0.71
Soluble reactive phosphorus (mg/L)	-0.52
No. of phytoplankton (no./ L)	-0.02
No. of zooplankton (no./L)	-0.54

Total nitrogen (mg/L)	0.95
Total phosphorus (mg/L)	0.40
Chlorophyll-a (mg/m^3)	0.53
Total dissolved solid (mg/L)	0.20
Dissolved oxygen (mg/L)	0.68
EC (µS/cm)	0.21
pH	0.00

DISCUSSION

Fish diversity and water quality parameters

All species collected during study period were reported by Jha and Shrestha (2004) from Rampur wetland. However, the number of fish species reported in the study is lower as compared to the previous studies reported by Jha and Shrestha (2004) and Oli et al. (2013). In this study, sampling of fish was done only from reservoir but in previous studies the sampling sites was ghol including reservoir. The use of selective gear might not be effective for bottom living fishes and not being caught during sampling period. Similarly, flooding in reservoir during rainy season might be another reason for fish decline because rainy season is breeding time for most of the fish species found in reservoir. Another possible reason might be due to acute shortage of water in reservoir during dry season (Jha & Shrestha, 2004).

Catch composition of Cypriniformes order was higher than other orders might be due to largest freshwater order. Oli et al. (2013) also reported Cypriniformes is dominating order with maximum species having higher catch composition from Rampur ghol. Gautam et al. (2016) also reported Cypriniformes is the most dominating order holding maximum number of species and contributing maximum catch composition in Rupa Lake.

The exotic fish *Oreochromis niloticus* and indigenous fish *Cirrhinus mrigala* were caught during sampling might be due to escape from the experimental cement pond near the hatchery of Fisheries Program.

The mean depth of the reservoir was significantly higher in summer and autumn season because of more rainfall in those seasons accumulating more water in reservoir. In August, the highest recorded depth of water was 195 cm because of high rainfall. The depth of reservoir in spring season was significantly lower because of no rainfall and more evaporation of surface water continuously.

The water temperature of reservoir was higher in summer season might be due to higher air temperature in that season. As the water temperature is influenced by air temperature and intensity of solar radiation. In winter season, low air temperature and low light intensity significantly lowering water temperature of reservoir. Jha and Shrestha (2004) also reported higher temperature in summer season month (June) and lower in winter season month (February). Similar result reported by Adhikari et al. (2017) from the Kulekhani Reservoir.

The secchi disk visibility values were appropriate in spring and winter season. The turbidity might not be caused by the phytoplankton only because the chlorophyll-*a* concentration was very low during study. The secchi disk visibility values were higher than desirable range in summer and autumn season because in August and September month the reservoir water was transparent and clear.

Because of the lower water temperature in the winter, a higher oxygen solubility may have contributed to the winter's highest dissolved oxygen concentration. In colder months, there is low microbial decomposition and low oxygen consumed. As the spring temperatures and light levels rise, the activity of plants, animals, and bacteria increases. More oxygen is produced and more oxygen is consumed resulting in dramatic fluctuations in daily dissolved oxygen levels and oxygen becoming less in the morning. Jha and Shrestha (2004) also reported higher water temperature in winter months in Rampur wetland. Similar trends were found by previous studies (Chaurasia & Tiwari, 2011; Niroula et al., 2010; Thapa & Pal, 2012) in different wetlands.

The higher values of electrical conductivity and total dissolved solids were observed in the winter season and lower value in summer season. The high EC and TDS value in the winter season might be due to more accumulation of ions and their total concentration in the reservoir and the water was not discharging at that season. Nazeer et al. (2018) also reported higher values in the dry season as compared to wet seasons.

The use of phosphorus-rich agricultural fertilizers in the watershed followed by agricultural runoffs into the reservoir may be the cause of the higher values of total phosphorus and soluble reactive phosphorus in the summer (Adhikari et al., 2017). Similar results reported by Thapa and Pal (2012) and Tuboi et al. (2017).

Total nitrogen was significantly higher in spring season might be due high-water temperature causes high metabolic rates of aquatic organism and high decomposition of organic matter resulting more nutrient in water. The result is accordance with the findings of Nazeer et al. (2018). Total ammonium nitrogen was significantly higher in summer season than spring and winter seasons might be due to surface runoff of ammonia rich fertilizers during rain. It can also be due to the high metabolic rate of fishes in reservoir causing more release of ammonia through gills and excreta. Oli et al. (2013) also reported similar results in Rampur ghol. The value of nitrite nitrogen was very low and suitable for fish and aquatic organisms.

The high concentration of nutrients, particularly nitrogen and phosphorus, from agricultural land as surface runoff that was used in rice fields in the reservoir area may be the cause of the higher density of phytoplankton in the summer. Pathak and Limaye (2012) and Dhanalakshmi et al. (2013) also reported the similar results and reported rain water carries lager amount of organic matter which caused excessive phytoplankton growth. Increased phytoplankton growth causes increased number of zooplanktons in the following season. Similar results reported by Adhikari et al. (2017) in Kulekhani Reservoir, Nepal.

Abundance, Richness and CPUE

Both abundance and CPUE were significantly higher in spring season, which might be due to less water depth (71 cm) and less water visible (25 cm) in reservoir and less rainfall than other seasons.

The correlation of fish abundance with water depth ($r = -0.92$) and secchi disk visibility ($r = -0.82$) were negative meaning less depth and less water visible (more turbid) of water in reservoir more fish abundance and higher catch per unit effort as well. Similarly, the dissolved oxygen concentration is positively related with fish abundance ($r = 0.68$) resulting more fish abundance in higher DO level in spring season (4.3 mg/L).

In addition, suitable water temperature, higher dissolved oxygen, phytoplankton and chlorophyll-a concentration also enhanced the activity of fishes in reservoir resulted more fish catch during netting. The mean abundance and CPUE was lower in summer and autumn season might be due to more water depth in reservoir and fish may easily escape during netting. As the macrophytes growth was higher in summer and autumn because of high nutrient and abundant sunlight. The presence of macrophytes makes difficult on netting and also acts as hidden place for fishes in reservoir.

Overall, the findings highlight that nutrient availability, dissolved oxygen, and water clarity are significant factors influencing fish abundance, while deeper waters and elevated levels of ammonia and nitrite negatively impact fish populations.

CONCLUSION

A total of 17 fish species belonging to 7 orders were recorded during study with higher catch composition of Cypriniformes order. The fish diversity changes with respect to seasons, higher number in autumn season (14) followed by spring and summer season (13) and low in winter season (10). The abundance and catch per unit effort of fishes were higher in the summer season. All the measured physical, chemical and biological water quality parameters were changes as seasons changes with most of them are suitable for fish species. The number of fish species were declined as compared to previous studies.

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